

Adapting standard maintenance approaches for mining excavators to actual operating condition

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Abstract. Significant portion of the annual calendar fund-time work of mining excavators spent on maintaining its working condition by carrying out preventive and repair regulatory activities and recovery in the event of emergency failures and maintenance and repair expenses constitute a significant proportion of the cost of excavation of mining rock. To assess the effectiveness of machinery a non-standard indicator, the coefficient of technical readiness, applied which does not have a single assessment methodology. At the present stage of machinery development, existing quarry dispatching systems allow you to allocate any of its elements from the fund-time of mining excavators: productive time, time spent in repair and maintenance and also classify other time costs of a particular machine which allowed an appropriate analysis. Analysis showed that at the current organization of MaR (maintenance and repair) there is significant potential to reduce repair impacts, as well as to ensure a reduction in the cost of routine maintenance, to remove maintenance and repair measures from the category of costly ones, at least for self-sufficiency without compromising the quality of these works and the reliability of the excavator as a whole.

1. Introduction

A large part of the annual calendar fund-time work of excavators involved in the extraction of minerals falls on downtime due to repairs, and the costs of maintenance and repair make up a significant proportion of the cost of excavating the mining rock.

The effectiveness of the use of equipment according to the criterion of its operability in most mining enterprises is estimated by the coefficient of technical readiness (C_{tr}) [1, 2]. In general, C_{tr} characterizes the technical level and reliability level of the facility, allowing you to compare the same type of mining equipment within the same mining enterprise.

Mining enterprises distinguish between planned and actual [3] coefficient of technical readiness, which are defined as the ratio of the difference between the calendar fund-time work of the planning period and the time of repair downtime (planned and actual respectively) to the calendar fund-time work of the planning.

Term 'coefficient of technical readiness' is often used in assessing mutual settlements between the Customer (operating organization) and the Manufacturer (in the particular case, supplier) of new equipment. When purchasing new equipment, the Supplier and the Consumer jointly determine the average value of the C_{tr} specified in the contract, which is guaranteed by the Supplier [4, 5]. Usually, during the warranty period, the coefficient of technical readiness of mining excavators is 0.80–0.88 C_{tr} .



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is also used to evaluate the effectiveness of the technical service when the repair units are outsourced or branded technical service.

The coefficient of technical readiness is not regulated by SSS (State Standard System) and is subjective in nature. So on some MPPs ((mining and processing plant) (cuts)), work on changing the teeth of the bucket and ropes is not included in the category of technical downtime affecting the C_{tr} , because they are classified as technological, while in other enterprises, these operations are included in the assessment of this coefficient.

It is often difficult to evaluate and qualify downtime due to the lack of clear objective criteria for accounting for certain categories of unproductive working hours.

Existing quarry dispatching systems make it possible to allocate productive operating time, time spent on repair and maintenance from the fund – time of mining excavators, as well as classify other time costs of a particular machine. The Modular System [6, 7] is used in most enterprises conducting open pit mining. The operating time data entering this system is largely dependent on the ‘operator’ entering the values into the system. In relation to the excavator, the operator is the driver-operator, who in the process of work must record all the downtime of the excavator by entering into the computer information about the operation of the equipment at a particular moment in time (loading, cleaning the sole, failure, waiting for the dump truck, etc.) [8].

2. Methodology for assessing the coefficient of technical readiness

The coefficient of technical readiness, as in equation (1), is defined as the ratio of the difference between the calendar fund - time and the actual time of repair downtime to the calendar fund - time of the estimated period:

$$C_{tr} = \frac{T_{cft} - T_{f.rep}}{T_{cft}} \quad (1)$$

where C_{tr} is the coefficient of technical readiness, T_{cft} is the calendar fund –time, $T_{f.rep}$ is the actual downtime of the excavator in repairs and waiting for repairs.

The main difference in the evaluation methods of C_{tr} is the determination of the time for repair work, specifically the accounting of downtime associated with the replacement of consumables (teeth and bucket protection, ropes, lubrication and its replacement), since they cannot be clearly regulated and to a large extent depend on the conditions and operating modes of the mining machine.

At one of the iron ore plants in Russia (hereinafter referred to as MPP), field observations of the operation of mining excavators of large unit capacity were carried out. The observations were carried out during the calendar year for two excavators with a bucket volume of 20 m³ [9, 10, 4], in this article designated as ECG №1 and ECG №2.

The C_{tr} calculation methodology used at MPP takes into account the time it takes to replace consumables. Thus, with the consistent performance of all scheduled maintenance recommended by the manufacturer according to the standards of frequency and duration, the maximum achievable C_{tr} , as in equation (2) and (3), per month in the absence of emergency repairs cannot exceed:

$$C_{tr} = \frac{T_{cft} - T_{f.rep}}{T_{cft}} = \frac{T_{cft} - (TM_{rep} + TM_m + TM_{el.m} + T_{l.r} + T_{pr.r} + T_{ret.r} + T_{teeth})}{T_{cft}} \quad (2)$$

$$720 - \frac{(0.5 \cdot 2 \cdot 30 + 1 \cdot 24 + 1 \cdot 12 + 0.5 \cdot 12 + 4 \cdot 4)}{720} = 0.844 \quad (3)$$

where TM_{rep} , TM_m , $TM_{el.m}$ – time for maintenance of replaceable, monthly, electrical machines, respectively; $T_{l.r}$, $T_{pr.r}$, $T_{ret.r}$, T_{teeth} – time to carry out work on the replacement of lifting ropes, pressure ropes, return ropes, bucket teeth, hours.

The frequency of replacement of consumables (ropes, teeth) was taken according to their actual consumption for the period of the experiment, the regulatory frequency and duration of work was adopted in accordance with the operating manual for these excavators.

In practice, the activities of mining enterprises and service companies to reduce the time for maintenance and repair, certain types of work are combined, for example:

1. Shift maintenance is carried out during the reception/change of the shift or at other organizational and technological breaks (when replacing teeth, ropes, waiting for vehicles), in particular it must be combined with other types of maintenance work.

2. Monthly maintenance of the electrical part is carried out in parallel with the monthly maintenance of the mechanical part.

Thus, C_{tr} in the case under consideration can be increased to the level of, as: in equations (4) and (5):

$$C_{tr} = \frac{T_{cft} - T_{f.rep}}{T_{cft}} = \frac{T_{cft} - (T_{Mm} + T_{H.r} + T_{Pr.r} + T_{Ret.r} + T_{Teeth})}{T_{cft}}, \quad (4)$$

$$720 - \frac{(1 \cdot 24 + 1 \cdot 12 + 1 \cdot 12 + 0.5 \cdot 12 + 4 \cdot 4)}{720} = 0.903 \quad (5)$$

3. Analysis of emergency failures of units and parts of excavators ECG №1 and ECG №2

During the operation of excavators ECG №1 and ECG №2, the most significant downtime was due to an emergency failure, both due to the fault of the manufacturer (factory defects of components and parts, these cases during the experiment are confirmed by bilateral acts) and a number of disputed cases are noted on the following units: ropes; pressure axis; handle; idler wheels; cast parts; drive unit.

The total time to restore and wait for repairs on the indicated units for two ECG machines №1 and ECG №2 amounted to 1054 hours out of 12384 hours of the calendar time-fund (CTF). Thus, the average time of emergency downtime at the above units is about 65 hours per month (table 1), and the average C_{tr} for the specified period was 0.75.

Table 1. Time for troubleshooting individual units and parts.

Unit name	Average troubleshooting time, h/month	The share of emergency downtime, % CTF	Notes
Pressure axis	27.7	3.85	Redesigned. Axes are in stock
Drive unit	10.6	1.48	Ultrasonic inspection of shafts and gears introduced
Handle	10.4	1.45	Structural reinforcements on operating machines have been performed. On the next issued ECG - the handle of a new design. Additional control introduced (X-ray, MTD)
Ropes (pressure, return, lift)	8.4	1.16	Changed suspension design. Recommendations on the use of rope d 60.5mm
Idler wheels	4.1	0.57	The lubrication system has been changed, and input quality control of the supplied bronze has been strengthened.
Casting defect	no data	0.50	Input quality strengthened.
TOTAL	≈65	9.0	

There is no doubt that the operation of mining equipment is impossible without emergency failures [11–13]. In practice, the work of mining enterprises of the Russian Federation for unplanned work to eliminate emergency failures lay about 24–27 hours a month, which is 3.3–3.8% of CTF.

For the analyzed period, emergency repairs of the above-described units of the ECG №1 excavators; ECG №2 excavators amounted to 9% of CTF. Of these, a large proportion (42%) was occupied by emergency breakdowns of the pressure axis, the causes of which are controversial [14, 15]. For the convenience of service, improving the quality of this service, mechanizing production and reducing economic costs during maintenance and repair of mining machines involved in carrying out

basic and auxiliary works in the implementation of mining technologies, work is underway to create mobile and autonomous technical means for carrying out delivery work, storage, regeneration and collection of used oils and lubricants as part of scheduled maintenance and repair work. However, when performing lubricating and filling operations with the help of mobile workshops, problems arise associated with forcing grease into the system due to the inability to create the necessary pressure with domestic metering pumps [16, 17].

Thus, the high share of emergency downtime (9%) after making changes to the design of excavators, including the use of on-board diagnostic systems and the transition to centralized lubrication systems with the solution of their refueling problems [18], tends to decrease. It is planned that according to the results of all warranty work to improve the design of excavators, the share of emergency failures will be within acceptable limits (3.3–3.8%). Based on the foregoing, in eliminating the causes of emergency failures, the average C_{tr} of excavators will be about, as in equation (6):

$$C_{tr} = 0.75 + (0.09 - 0.035) = 0.81 \quad (6)$$

After eliminating the accident rate of the listed units, the potential for increasing C_{tr} by the factor ‘manufacturer’ will be exhausted. Therefore, to achieve the planned $C_{tr} = 0.85$ and above, eliminating the accident rate of the nodes is not enough.

With the elimination of accidents and bringing the duration of repairs to standard indicators, it is possible to achieve C_{tr} at the level of, as in equation (7):

$$C_{tr} = 0.75 + (0.09 - 0.035) + 0.092 = 0.90 \quad (7)$$

4. Analysis of the time spent on maintenance and repair of excavators

Based on the statistical data of the work of excavators ECG №1 and ECG №2, Table 2 shows a comparison of the actual and achieved time spent on maintenance and repair, as well as the planned indicators of the repair department of the MPP (table 2).

Table 2. Comparison of the average planned, actual and achieved time spent on maintenance and repair of the excavator from 1 January to 30 April.

Type of repair	Duration of repairs per month, h			Deviation of actual time from standard	
	Actual	GOK plan	Service company standard	Time, h	% CTF
Shift maintenance (not taken into account in amount per month)	No data	30	30	–	–
Monthly Maintenance	61	24	24	+37	+5.1
Monthly Electric Maintenance	12	12	12	0	0
Consumables replacement work					
Teeth replacement	24.4	16	12	+11.5	+11.5
Protection replacement	1.1	16	2	+11.5	+1.6
Lift rope replacement	17	12	8	+9	+1.3
Pressure rope replacement	18	12	8	+10	+1.4
Return rope replacement	3	6	4	–1	–0.1
TOTAL	136	82	70	+66.5	+9.2

In order to increase the operating time of the bucket teeth, to reduce the time for their replacement, as well as to exclude cases of emergency tooth breakages, it is recommended to use teeth tested by the manufacturer on excavators ECG № 1 and ECG № 2. During the experiment, MPP used bucket teeth that did not correspond to the design documentation. The result is a decrease in C_{tr} .

Conclusions

1. The average actual time for maintenance and repair of excavators ECG №1 and ECG №2 is 136 hours per month compared to 82 hours according to the plan of the MPP repair unit. At the same time, the service company achieved the duration of repair operations – 70 hours per month.

2. When performing maintenance and repair work on excavators, there is the potential to reduce the repair time by 66.5 hours per month, which is equivalent to an increase in C_{tr} by 9.2 points.

Thus, subject to the regulatory deadlines, a reserve of time is provided for unplanned and emergency repairs to repair the excavator.

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